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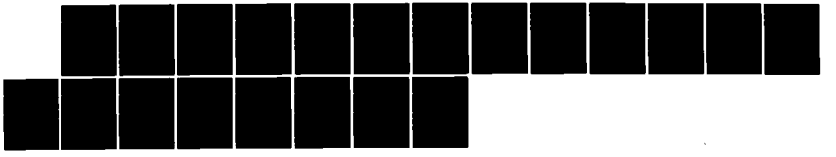

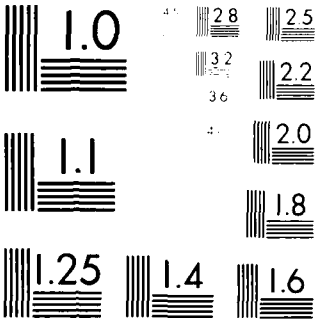
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This report summarizes research on resonantly enhanced multiphoton absorption, dissociation, and ionization processes in atoms and molecules. Multiphoton processes are studied using from one to three independently tunable visible and/or UV laser beams in order to establish both the underlying physics and the high degree of selectivity of multiphoton processes. Measurements are made to probe both the formation of excited molecular states and the subsequent behavior of excited states either in the presence or in the absence of further intense

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ANNUAL SUMMARY REPORT

HIGH-RESOLUTION SPECTROSCOPY AND DYNAMICS OF MULTIPHOTON PROCESSES IN ATOMS AND MOLECULES

(Contract No. N00014-85-F-0015)

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I. SCIENTIFIC PROBLEM

Rapid advances in laser and detector technologies are making it possible to investigate molecular photophysics and photochemistiry in powerful new ways. For example, resonantly enhanced multiphoton ionization measurements, in which the total (or the mass selected) ion current is monitored as a function of laser wavelength, have yielded extensive and often novel information on the spectroscopy of the resonant intermediate states. The addition of an electron energy analyzer to determine the energy of the ejected electrons provides information on the branching ratios into different electronic, vibrational, and rotational levels of the product ion. This allows one to probe directly the photoionization dynamics of excited states. Such studies are motivated by the prospect of understanding the fundamental mechanisms governing the excitation, ionization, relaxation, and decay of selectively excited molecular states. Furthermore, the resulting ability to selectively probe molecular excitation and decay has direct bearing on a variety of applied fields, e.g. ultrasensitive detection of unstable, reactive, or trace species, the characterization of the physics and chemistry of excited states that mediate the effects of ionizing radiation on matter, isotope separation, laser-modified chemistry, modeling of plasmas, modeling the physics and chemistry of the atmosphere, and a variety of defense-related applications such as guidance and communications in disturbed atmospheres. The present program is aimed at developing the experimental capabilities and basic understanding necessary to carry out selective excitation/detection experiments on a broad range of atomic and molecular systems.

II. SCIENTIFIC AND TECHNICAL APPROACH

The program involves the following three major activities. First, in order to specify a sequence of resonant multiphoton transitions in a molecular target, it is necessary to have a precise knowledge of the rovibronic energy levels for each of the electronic states in the excitation sequence. For many molecules (including well-studied diatomic molecules such as N_2 and O_2), this information is fragmentary or lacking, especially for those electronic states that cannot be excited from the ground electronic state using single photon techniques. Thus, the first research area involves the study of the high resolution spectroscopy of excited electronic states, particularly electronic

states that are dipole-forbidden in single photon absorption. Second, it is necessary to establish the mechanisms and dynamical parameters governing multiphoton processes. For example, in order to design the most selective and sensitive excitation scheme, one must know the cross sections for each step, the decay mechanisms and the decay rates of the intermediate states, and the cross sections for all competing excitation processes, including nonresonant ones. Such information is largely unknown at this time. Third, this work involves the development of advanced electron energy and ion mass analyzers that are designed specifically for their compatability with pulsed laser excitation sources.

A hemispherical electron spectrometer and time-of-flight mass spectrometer have been used in this work to date. The rotable electron spectrometer consists of two copper hemispheres of 5.1 cm mean radius, with entrance and exit "zoom" lenses that focus the electron source onto a virtual entrance slit at the entrance to the hemispheres, and then onto the channeltron detector after energy analysis. Using a HeI resonance line photoionization source, this spectrometer has acheived a resolution of 5-6 meV. Using the laser photoionization source, the spectrometer has been operated at a resolution of 20 meV. Higher resolution is possible; however, the low duty factor ($\sim 10^{-7}$) associated with the 10 Hz Nd:YAG pulsed laser source usually requires operating at a resolution of at least 20 meV in order to achieve reasonable counting rates. Two new electron spectrometers, optimized for use with pulsed laser sources, are presently under construction and will provide both increased collection efficiency and higher electron energy resolution. These are described in Section III.13 below.

The time-of-flight mass spectrometer, originally added to the photoelectron spectrometer in order to perform photoion-photoelectron coincidence studies using a resonance lamp, is presently operated independently of the photoelectron spectrometer. The mass spectrometer consists of 10 stack plates, a 20 cm drift region, and a high current channeltron detector. A new differentially pumped, high resolution time-of-flight mass spectrometer for use with reactive or corrosive species is presently under construction.

In addition, the following lasers and ancillary laser equipment are presently available in the laboratory: (1) a Molectron Nd:YAG oscillator and

amplifier (Model MY34-10) with 2nd, 3rd, and 4th harmonic generation crystals, an intracavity etalon for line narrowing, and a single-axial mode selector device; (2) A Molectron dye laser (Model DL18P) with a flowing dye cell amplifier and a doubling crystal which tracks via computer control; (3) a Questek excimer laser (Model 2460); (4) a Lambda-Physik dye laser (Model FL2002E); (5) two computer-controlled, double-grating dye lasers of the modified Littman type -- these ANL-built lasers are capable of producing output with a linewidth of 0.03 cm^{-1}; (6) two Inrad autotracking frequency doublers; (7) a Lasertechnics Fizeau wavemeter interfaced to a PDP-11/23 computer for measuring the absolute wavelength of a cw laser (to 2 parts in 10^7) or a pulsed laser (to approximately 2 parts in 10^6); (8) a scanning Fabry-Perot interferometer; (9) an assortment of accessory equipment and parts, such as power meters, mounting hardware, mirrors, prisms, dichroic beamsplitters, and retardation optics; and (10) a PDP 11/03 and a PDP 11/23 microprocessor. Other equipment, which is readily available, but which has not been used in the initial experiments, include cooled fluorescence detectors, a 0.2 meter vacuum monochromator, a pulsed supersonic molecular beam source, a microwave free radical source, high temperature vapor sources, and single photon VUV capabilities.

Summarizing, we are able to probe atoms and molecules with a fully flexible composite laser probe and to measure directly the photoions, photoelectrons, and fluorescent photons. Neutral fragments also can be monitored by subsequent ionization or by laser-induced fluorescence. Spectroscopic and dynamical information is then obtained by monitoring these detection channels as a function of the frequencies and polarization states of one or more of the components of the composite laser probe.

III. PROGRESS

During the past three years, this program has produced several prototype REMPI studies of small molecules of fundamental interest. Among these were the first (m+n) REMPI studies of the closed-shell diatomic molecules H_2, N_2, and CO with photoelectron energy analysis. (Here (m+n) denotes an m photon transition to the resonant intermediate state followed by ionization of that state by the absorption of n additional photons, all occurring during a single laser pulse.) These studies showed that REMPI/PES experiments are indeed

possible on such molecules, even using a space-dispersive (i.e., a low collection efficiency) electron energy analyzer. These (m+n) REMPI/PES studies also demonstrated that significant complications arise in the photoelectron spectrum when n is greater than 1, as a result of accidental resonances at energies between the m-photon resonance and the (m+n)-photon level. For this reason, our current studies are confined to (m+1) or (m+1+1) excitations (the latter with three independently tunable lasers). Examples of such work include (3+1) REMPI/PES studies on H_2 and N_2. Both of these molecules present a difficult experimental challenge owing to their large ionization potentials; however, they are the best systems with which to begin establishing a basic understanding of REMPI processes in molecules, since they are the most amenable to theoretical interpretation.

During the most recent contract period, a substantial amount of new work was completed. While some of it has already been published, much of it is either in press or is presently being prepared for submission. Examples of this work include single and multicolor REMPI experiments on the molecules N_2, CO, O_2, NO, NeXe, ArXe, KrXe, Xe_2, and on the atoms C, I, and S using both mass spectrometry and photoelectron spectroscopy to analyze the products of the ionizations. These studies are described briefly below.

1. Photoionization of $^1\Sigma_u^+$ and $^1\Pi_u$ Rydberg and valence states of N_2. Since both the ground state and the first excited state of the N_2^+ ion can be accessed in the ionization step of the REMPI process, electronic as well as vibrational and rotational branching ratios may be determined. Furthermore, since the neutral excited states of N_2 have been very well characterized, both experimentally and theoretically, N_2 is a particularly attractive system for study using REMPI/PES techniques. Photoelectron spectra were obtained by (3+1) REMPI via the b $^1\Pi_u$, c $^1\Pi_u$, c' $^1\Sigma_u^+$, and o $^1\Pi_u$ states. The c $^1\Sigma_u^+$ and c' $^1\Pi_u$ states are the $3p\pi_u$ and $4p\sigma_u$ Rydberg states, both of which converge to the X $^2\Sigma_g^+$ ground state of the ion; the o $^1\Pi_u$ state is the $3s\sigma_g$ Rydberg state that converges to the A $^2\Pi_u$ state of the ion; and the b $^1\Pi_u$ state is a valence state having two primary electron configurations, both of which differ from the X $^2\Sigma_g^+$ and A $^2\Pi_u$ states of N_2^+ by two orbitals. In this energy region, the b $^1\Pi_u$, c $^1\Pi_u$, and o $^1\Pi_u$ states are strongly mixed by a homogeneous perturbation. Hence, it is possible to study photoionization from Rydberg states (including core-excited Rydberg states), valence states, and certain

perturbed levels that are complex mixtures of these.

2. Two-color REMPI and REMPI/PES of N_2 and CO. Two color REMPI experiments have been performed on N_2 and CO. For CO, two photons of the pump laser were used to excite the A $^1\Pi$, v=3 level, followed by probe laser excitation of the C $^1\Pi$, v=0 level. For N_2, two photons of the pump laser were used to excite the a $^1\Pi_g$, v=1 level, followed by probe laser excitation of the c' $^1\Sigma_u^+$, v=1,2, c $^1\Pi_u$, v=1,2, o $^1\Pi_u$, v=0, and b $^1\Pi_u$, v=6 levels. Photoelectron spectra were obtained following two color REMPI for a number of these transitions in N_2. While these studies are of interest in their own right, it is our goal to use such two color transitions as the basis for studying autoionizing states by adding a third laser to excite transitions from the upper level of the probe transition into the ionization continuum.

3. Gerade autoionizing states of N_2. These experiments use (2+1+1) REMPI to study the gerade autoionizing states of N_2. The first laser excites the a $^1\Pi_g$, v=1 level via a two photon transition; the second laser excites the c' $^1\Sigma_g^+$, v=0 level; and, finally, a third laser is used to excite autoionizing transitions which lie above the first ionization threshold. Because the overall process involves four photons, the final state is of gerade (g) symmetry, i.e., the opposite of that reached by single photon excitation. The third laser is scanned through a region of the ionization threshold, thus providing a means to study the autoionization structure in great detail. Preliminary data have been taken and show the feasibility of this three color experiment.

4. Gerade excited states of O_2. These experiments use (2+1) REMPI to study the gerade discrete excited states of O_2. A band with sharp structure was observed at a total energy of about 8.6 eV and was tentatively assigned as the single photon forbidden C $^3\Pi_g$, v'=2 ← X $^3\Sigma_g^-$, v"=0 transition. These preliminary results suggest a number of possible studies on O_2 using REMPI. In particular, using this two photon transition as the first step of a double resonance study, it may be possible to examine the highly excited states of molecular oxygen in great detail. At present, there are no reports of Rydberg series converging to the first ionization threshold of O_2, and such a study would be very significant.

5. Rydberg states of NeXe, ArXe, KrXe, and Xe_2 using REMPI. In this work, (2+1) REMPI spectra of NeXe, ArXe, KrXe, and Xe_2 were determined in the

energy region containing the atomic Xe^* 5d and 6p states. The van der Waals dimers were obtained using an unskimmed, cw supersonic molecular beam source. Several new progressions of vibronic bands were observed for all four rare gas van der Waals molecules. These bands arise from two photon bound-bound transitions from the ground electronic state to various resonant intermediate states. Because two photon transitions from the ground state of Xe_2 access states of gerade symmetry, none of the homonuclear bands have bee observed in earlier single photon absorption studies.

6. Photoelectron spectra of ArXe, KrXe, and Xe_2. We have obtained the photoelectron spectra of ArXe, KrXe, and Xe_2 without interference from either atomic or (in the case of the heteronuclear dimers) homonuclear dimer photoelectron peaks by using REMPI to selectively ionize the van der Waals molecule of interest. The photoelectron spectra of ArXe and KrXe are the first such spectra of a heteronuclear rare gas dimer obtained by any technique. The REMPI/PES of Xe_2 were recorded at a number of wavelengths and the relative intensities of different electronic states of Xe_2^+ are strongly dependent on the resonant intermediate level, thus providing information on the electronic character of that level. In addition, the absence of photoelectrons from atomic Xe allows the first observation of photoelectron peaks corresponding to the weakly bound C $^2\Pi_{3/2u}$ and D $^2\Sigma^+_{1/2g}$ electronic states of Xe_2^+, thus providing lower limits for the dissociation energies of these states. Thus, REMPI/PES is shown to be a powerful technique for the study of the photoelectron spectrum of a minor component in a mixture.

7. Predissociation and ionization of excited states of rare gas van der Waals dimers observed using REMPI/PES. In addition to photoelectron peaks due to direct photoionization of the rare gas dimers, these spectra often show a number of additional peaks. These peaks are due to predissociation of the resonant intermediate state followed by photoionization of the excited atomic fragment, e.g., $KrXe^* \rightarrow Kr + Xe^* \rightarrow Kr + Xe^+ + e$. Because the excited atomic fragments are ionized within the 5 nsec laser pulse, which in most instances is shorter than both the fluorescence lifetime of the level and the mean collision time, the relative intensities of the photoelectron peaks provide information on the nascent branching ratios of the predissociation process. Although similar information has been obtained previously on a number of systems using dispersed fluorescence to determine the electronic state of the

excited fragment, in some instances fluorescence may be extremely weak or forbidden. Thus, REMPI/PES provides an method for studying these "dark" channels.

8. Two photon spectroscopy of autoionizing Rydberg states of NO. We have determined (2+1) REMPI spectra of supersonically cooled NO in the energy region between the NO^+ $^1\Sigma^+$ $v^+ = 0$ and 2 thresholds in order to examine autoionizing discrete levels. Recent theoretical calculations have shown that this region is rich in interactions among Rydberg states, bound valence states, and dissociative valence states. These interactions profoundly affect the photoionization dynamics. Single photon ionization cross sections obtained in this region have relatively low wavelength resolution. The present two photon ionization cross sections have about a factor of 20 improvement in resolution, which will permit a far more detailed comparison with theory. In addition, the selection rules for two photon absorption allow the direct excitation of ng Rydberg states.

9. Angular distributions following photoionization of excited states of atomic carbon. Atomic carbon in both the ^3P ground state and the ^1D excited state was prepared by UV multiphoton dissociation of carbon tetrachloride (CCl_4). Photoelectron angular distributions were obtained following (2+1) REMPI via the $3p\ ^1S_0 \leftarrow {}^1D_2$ transition using linear polarized light and via the $3p\ ^3D_2 \leftarrow {}^3P_0$ transition using both linear and circular polarized light. These angular distributions are interesting for a number of reasons. First, because carbon is a first row atom, it represents a theoretically tractable case in which electron correlation effects can be studied in photoionization of an open-shell atom. Second, by using circular polarized light to prepare the resonant intermediate state, photoionization from a single magnetic sublevel can be observed. Third, the nuclear spin of carbon is zero, which greatly simplifies the analysis by removing the possibility of hyperfine effects. Finally, very few experimental studies exist for atomic carbon photoionization, due primarily to the difficulty in producing a sample of this extremely refractory material. Here, we have overcome the sample preparation problem by using laser photodissociation of a volatile sample (CCl_4) to produce the atomic carbon beam.

10. Two-photon spectroscopy of np and nf Rydberg states of atomic iodine. In this work, the (2+1) REMPI spectrum of atomic iodine was

determined in the region of the first ionization potential ($I^+ {}^3P_2$). Rydberg series corresponding to the odd parity, single photon forbidden ($^3P_2$)np and nf excitations, are observed to high n (~34) for the first time. Atomic iodine in both the $^2P_{3/2}$ and $^2P_{1/2}$ spin orbit components of the ground state was prepared by photodissociation of CH_3I.

11. Autoionizing Rydberg states in atomic iodine. In an extension of the above experiment, two color excitation was used to access the even parity, single photon allowed manifold of autoionizing Rydberg states converging to the higher ionization potentials of iodine. The first laser is used to produce the atomic iodine and to pump it via a two photon transition to low lying np Rydberg states; the second laser is then used to probe transitions from these low lying states to high lying, even parity Rydberg states converging to the excited states of I^+. These high lying Rydberg states may autoionize and the transitions are detected by monitoring the I^+ ion signal.

12. Observation of spin-forbidden autoionization in atomic sulfur. We have performed two-color REMPI studies on atomic sulfur. In this work, the first laser is used to produce atomic sulfur in the excited $^1D_2$ state by photodissociation of carbon disulfide (CS_2) and to pump these excited atoms to the 4p $^1F_3$ state via a two photon transition. The second laser is used to probe transitions from the $^1F_3$ level to the previously unobserved singlet Rydberg states converging to the ^2D excited state of S^+. Although these Rydberg states are above the ^4S ground state of S^+, they are forbidden to autoionize in an LS coupling scheme. Therefore, the widths and profiles of the observed autoionizing peaks provide new information on the effects of spin-orbit coupling as manifested by the breakdown of LS coupling in open shell atoms.

13. Instrumentation development. In addition to these experimental studies, we are also in the process of constructing three advanced mass and electron energy analyzers, which are designed specifically for use with pulsed lasers and which are optimized for collection efficiency, resolution, and versatility. The first is a "magnetic bottle" electron spectrometer, which combines high resolution with high collection efficiency. The spectrometer consists of an ionization region, a magnetic lens that parallelizes electrons with different ejection angles, a 50 cm flight tube, and a channel-plate detector. We estimate that the magnetic bottle electron spectrometer will

produce a data collection rate for high resolution electron spectra that is 3-4 orders of magnitude greater than that of our current instrument. The first signal from the magnetic bottle spectrometer was recorded during the past two weeks, and we expect to have the instrument fully operational during the next contract period.

Because the magnetic bottle spectrometer does not permit photoelectron angular distribution measurements to be made in a straightforward and reliable manner nor does it allow the investigation of physical processes that may be altered by a strong magnetic field, a complementary spectrometer is necessary. We are presently completing a 10.2 cm mean radius hemispherical electron spectrometer, similar in design to the presently used 5.1 cm mean radius spectrometer, but tailored to the pulsed laser excitation source. In order to improve the collection efficiency, this instrument will be equipped with an optically coupled area detector, which will enable the measurement of 1024 energy channels simultaneously. The basic instrument, consisting of the hemispheres and the entrance and exit lenses, is complete and assembled. Together the magetic bottle spectrometer and the 10.2 cm hemispherical spectrometer provide a unique and comprehensive REMPI/PES capability.

The third apparatus under construction is a time-of-flight mass spectrometer, which will be designed for maxiumum versatility and ruggedness. The major improvement over the existing time-of-flight mass spectrometer is the separation of the ionization and detection regions into individually pumped vacuum chambers, thereby allowing the use of corrosive gases and/or high pressures in the ionization region. Both of these operating conditions are presently impossible due to the exposure of the channeltron detector, which is very sensitive to contamination and is subject to electrical breakdown at high chamber pressure.

IV. PUBLICATIONS

The papers, abstracts of conference presentations, and invited talks prepared as part of this ONR program are listed on the following pages. New items during the current contract period are papers 20-25, abstracts 17-23, and invited talks 32-36.

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1. P. M. Dehmer, and J. L. Dehmer, "Observation of Bending Modes in the $X\ ^2\Pi_u$ State of the Acetylene Ion Using HeI Photoelectron Spectrometry," J. Electron Spectrosc. 28, 145 (1982).

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14. P. M. Dehmer, P. J. Miller, and W. A. Chupka, "Photoionization of N_2^+ X $^1\Sigma_g^+$, v"=0 and 1 Near Threshold -- Preionization of the Worley-Jenkins Rydberg Series," J. Chem. Phys. 80, 1030 (1984).

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22. S. T. Pratt, "Two-Photon Spectroscopy of np and nf Rydberg States of Atomic Iodine," Phys. Rev. A (in press).

23. P. M. Dehmer, "Rydberg States of the $ArCO_2$ and $KrCO_2$ van der Waals Molecules," J. Chem. Phys. (in press).

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ABSTRACTS OF CONFERENCE PRESENTATIONS

1. J. L. Dehmer, E. D. Poliakoff, and P. M. Dehmer, "Photoelectron Angular Distributions From Multiphoton Ionization. Seven Photon Ionization of Kr at 532 nm," XIII DEAP Meeting, 3-5 December 1981, New York, New York, Bull. Am. Phys. Soc. 26, 1322 (1981).

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3. P. M. Dehmer and S. T. Pratt, "Systematics of Electronic Structure in Rare Gas van der Waals Molecules," (invited talk), NATO Advanced Study Institute on Photophysics and Photochemistry in the Vacuum Ultraviolet, 15-28 August 1982, Lake Geneva, Wisconsin, Book of Abstracts.

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5. P. M. Dehmer, "VUV Spectroscopy of Rare Gas van der Waals Dimers," (invited talk), Proceedings of the 2nd European Workshop on Molecular Spectroscopy and Photon-Induced Dynamics, September 27-30, 1982, Flevopolder, The Netherlands, AMOLF-Report #83-3, p. 11.

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7. S. T. Pratt, P. M. Dehmer, and J. L. Dehmer, "Resonant Multiphoton Ionization of H_2 via the $B\ ^1\Sigma_u^+$ State with Photoelectron Energy Analysis," XIV DEAP Meeting, 23-25 May 1983, Boulder, Colorado, Bull. Am. Phys. Soc. 28, 808 (1983).

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13. J. L. Dehmer, P. M. Dehmer, and S. T. Pratt, "Photoelectron Studies of Excited Molecular States. H_2 $^1\Pi_u$ and N_2 o_3 $^1\Pi_u$," XIII International Conference on Quantum Electronics, Anaheim, California, 18-21 June 1984, Book of Abstracts.

14. P. M. Dehmer, P. J. Miller, and W. A. Chupka, "Photoionization of Vibrationally Excited N_2," XV DEAP Meeting, 30 May - 1 June 1984, Storrs, Connecticut, Bull. Am. Phys. Soc. 29, 798 (1984).

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22. P. M. Dehmer, J. L. Dehmer, and S. T. Pratt, "Resonantly Enhanced Multiphoton Ionization and Photoelectron Spectroscopy of NeXe, ArXe, KrXe, and Xe_2," Proceedings of the Fourteenth International Conference on the Physics of Electronic and Atomic Collisions, Palo Alto, California, 24-30 July 1985, p. xxx.

23. S. T. Pratt, P. M. Dehmer, and J. L. Dehmer, "Multiphoton Studies of Highly excited States of Atomic Iodine," Proceedings of the Fourteenth International Conference on the Physics of Electronic and Atomic Collisions, Palo Alto, California, 24-30 July 1985, p. xxx.

INVITED TALKS, COLLOQUIA, AND SEMINARS

1. P. M. Dehmer, "Systematics of Electronic Structure within Families of van der Waals Molecules as Revealed by VUV Spectroscopy," Interdisciplinary Physical Sciences Seminar, Yale University, 30 November 1981.

2. P. M. Dehmer, "Systematics of Electronic Structure in Rare Gas van der Waals Molecules," Chemistry Department Seminar, Brookhaven National Laboratory, 19 January 1982.

3. P. M. Dehmer, "Systematics of Electronic Structure Within Families of van der Waals Molecules as Revealed by VUV Spectroscopy," Atomic and Molecular Sciences Seminar, Argonne National Laboratory, 18 February 1982.

4. P. M. Dehmer, "Systematics of Electronic Structure Within Families of van der Waals Molecules," Chemistry Department Colloquium, Illinois Institute of Technology, 12 March 1982.

5. P. M. Dehmer, "Systematics of Electronic Structure Within Families of van der Waals Molecules," Optical Physics - Chemical Physics Seminar, University of Maryland, 20 April 1982.

6. P. M. Dehmer, "Dissociation in Small Molecules," Discussion Leader, First International Workshop on Desorption Induced by Electronic Transitions (DIET-I), Williamsburg, Virginia, 12-14 May 1982.

7. P. M. Dehmer, "Systematics of Electronic Structures Within Families of van der Waals Molecules," Chemistry Department Seminar, University of Illinois at Chicago Circle, 18 May 1982.

8. J. L. Dehmer, "Molecular Photoionization Dynamics - Progress and Prospects," Physics Colloquium, University of Chicago, 27 May 1982.

9. P. M. Dehmer, "Molecular Spectroscopy - Where are the New Frontiers?", Programmatic Division Directors' Talk, Argonne National Laboratory, 7 June 1982.

10. J. L. Dehmer, "Overview of Experimental and Theoretical Studies of Resonance Processes in Molecular Photoionization by Single-Photon and Multiphoton Excitation," Gordon Research Conference on Electron Spectroscopy, Wolfeboro, New Hampshire, 19 July 1982.

11. P. M. Dehmer, "VUV Spectroscopy of Rare Gas van der Waals Dimers," NATO Advanced Study Institute on Photophysics and Photochemistry in the Vacuum Ultraviolet, Lake Geneva, Wisconsin, 19 August 1982.

12. P. M. Dehmer, "VUV Spectroscopy of van der Waals Dimers and Heavier Clusters," 2nd European Workshop on Molecular Spectroscopy and Photon-Induced Dynamics, Flevopolder, The Netherlands, 27 September 1982.

INVITED TALKS, COLLOQUIA, AND SEMINARS - Continued

13. J. L. Dehmer, "Multiphoton Ionization as a Probe of Molecular Photoionization Dynamics," U.S./Japan Seminar on Electron-Molecule Collisions and Photoionization Processes, Pasadena, California, 26 October 1982.

14. J. L. Dehmer, "Resonant Processes in Molecular Photoionization," Meeting of the American Physical Society, Los Angeles, California, 24 March 1983.

15. P. M. Dehmer, "Photoelectron Spectroscopy Following Resonantly Enhanced Multiphoton Ionization," Workshop on Experiments, Argonne National Laboratory, 16 April 1983.

16. P. M. Dehmer, "Decay of Rydberg States via Autoionization and Predissociation," Fourteenth Meeting of the Division of Electronic and Atomic Physics, Boulder, Colorado, 23 May 1983.

17. J. L. Dehmer, "Resonant Processes in Molecular Photoionization," Gordon Research Conference on Atomic Physics, New London, New Hampshire, 8 July 1983.

18. J. L. Dehmer, "Resonant Multiphoton Ionization as a Coincidence-Equivalent Means for Studying Photoionization of Excited Molecular States," International Workshop on Atomic and Molecular Photoionization, Berlin, West Germany, 25 July 1983.

19. P. M. Dehmer, "Photoionization of Clusters," International Workshop on Atomic and Molecular Photoionization, Fritz-Haber-Institut der Max-Planck Gesellschaft, Berlin, West Germany, 26 July 1983.

20. S. T. Pratt, "Multiphoton Ionization as a Probe of Excited State Photoionization Dynamics," Atomic and Molecular Science Seminar, Argonne National Laboratory, 10 October 1983.

21. S. T. Pratt, "Photoionization Dynamics from Excited Molecular States," Chemical Physics Seminar, The Aerospace Corporation, Los Angeles, California, 24 October 1983.

22. S. T. Pratt, "Multiphoton Ionization as a Probe of Excited State Photoionization Dynamics," Interdisciplinary Science Seminar, Yale University, 28 November 1983.

23. S. T. Pratt, "Multiphoton Ionization as a Probe of Excited State Photoionization Dynamics," Chemistry Department Seminar, Virginia Commonwealth University, 29 November 1983.

24. S. T. Pratt, "Multiphoton Ionization as a Probe of Excited State Photoionization Dynamics," Chemistry Department Seminar, University of Nevada, 13 January 1984.

25. J. L. Dehmer, "Photoionization Dynamics of Selectively Excited Molecular States," Chemical Physics Seminar, California Institute of Technology, 14 February 1984.

INVITED TALKS, COLLOQUIA, AND SEMINARS - Continued

26. J. L. Dehmer, "Photoionization Dynamics of Selectively Excited Molecular States," Chemical Physics Seminar, University of Southern California, 16 February 1984.

27. P. M. Dehmer, "Photoionization of Excited Molecular States Using Multipl on Excitation Techniques," Second Topical Meeting on Laser Techniques in the Extreme Ultraviolet, Boulder, Colorado, 5-7 March 1984.

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29. S. T. Pratt, "Survey of Recent Multiphoton Ionization Studies Using Electron Spectroscopy," Gordon Research Conference on Electron Spectroscopy, Wolfeboro, New Hampshire, 16 July 1984.

30. P. M. Dehmer, "Photoelectron Studies of Excited Molecular States," Third International Conference on Multiphoton Processes, Crete, Greece, 5-11 September 1984.

31. P. M. Dehmer, "Photoionization Studies of Ground and Excited States of Molecules -- Progress and Prospects," Chemical Physics Seminar, University of Indiana, 25 October 1984.

32. J. L. Dehmer, "Dynamics of Photoelectron Escape from Molecular Fields," Physics Division Colloquium, University of Oregon, 29 November 1984.

33. P. M. Dehmer, "Interaction of Discrete and Continuum States," Chemical Physics Institute Seminar, University of Oregon, 30 November 1984.

34. P. M. Dehmer, "Laser Probes of the Formation and Transformations of Excited Molecular States," Board of Governors, Argonne National Laboratory, 18 January 1985.

35. P. M. Dehmer, "Spectroscopy and Dynamics of Excited Molecular States Using Multiphoton Techniques," Sixteenth Meeting of the Division of Electron and Atomic Physics, Norman, Oklahoma, 31 May 1985.

36. J. L. Dehmer, "Dynamics of Photoelectron Escape from Molecular Fields," Physics Division Colloquium, Los Alamos National Laboratory, 6 June 1985.

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